

# PATENT SPECIFICATION

DRAWINGS ATTACHED

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## COMPLETE SPECIFICATION

### Improvements in Metallic Carbide Filament Lamps

We, GENERAL ELECTRIC COMPANY, a Corporation organized and existing under the laws of the State of New York, United States of America, residing at 1 River Road, Schenectady 5, New York, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed, is to be particularly described in and by the following statement:—

This invention relates generally to electric incandescent lamps comprising a sealed light-transmissive bulb or envelope containing an incandescible filament, and more particularly to lamps having filaments of highly refractory metallic carbide such, for example, as carbide of tantalum or allied metals such as hafnium, zirconium and niobium and mixtures or alloys thereof.

It has been proposed in the past to employ filaments of metallic carbides such as tantalum, because of their ability to withstand extremely high temperatures, even exceeding those permissible with the conventional tungsten filament. For that reason, and because of selective emissivity similar to that of tungsten, carbides such as tantalum carbide are useful as an efficient source of high brightness white light. However, a limitation upon the use of carbide filaments is decomposition which results in loss of carbon with consequent lowering of the melting point and shortening of lamp life. Loss of carbon also increases the resistance so that the power into the lamp and the light radiated will both decrease when the lamp is operated at constant voltage. Attempts have been made to overcome or retard decarburization of the filament by employing a filling of carbon-bearing gas in the lamp envelope. However, tests have shown that the concentration of the gases decreases in time so that the filament nevertheless loses carbon.

It is therefore an object of the present in-

vention to provide improved means for maintaining a carbide filament at a substantially constant state of carburization.

The invention consists in an electric incandescent lamp comprising a sealed light-transmissive envelope and within this envelope, an incandescible filament composed of carbide of a metal of the group consisting of tantalum, hafnium, niobium and zirconium or mixtures thereof, a source of hydrogen, and a quantity of uncombined solid carbon, which carbon is located in effective range of atomic hydrogen formed in the vicinity of said filament and migrating to said solid carbon to effect a cyclic reaction by formation of a carbon-bearing gas available for thermal decomposition in the vicinity of said filament to release carbon for reaction with said filament so as to keep its carbon content at a desired fixed value and to also release hydrogen for continuation of the cyclic reaction.

It is believed that the atomic hydrogen reacts with the carbon to form a hydrocarbon gas. The hydrocarbon is dissociated at the filament, and the carbon from this dissociation arrives at the carbide filament at a rate equal to the rate of loss of carbon from the carbide filament. The hydrogen resulting from the dissociation is again thermally dissociated at the filament to form atomic hydrogen for continuation of the cycle. The process is self regulating, the hydrocarbon pressure remaining at the same level. If the hydrocarbon pressure increases, the amount of atomic hydrogen decreases, so that the rate of formation of hydrocarbon decreases.

Further features and advantages of the invention will appear from the following description with reference to the accompanying drawing wherein Figures 1, 2 and 3 show examples of lamps comprising the invention.

Referring to Figure 1, the lamp illustrated therein comprises a glass bulb or envelope 1 containing a coiled wire carbide filament 2

which is supported by a pair of lead wires 3 which are sealed through a press or pinch seal 4. The bulb 1 contains a source of hydrogen which may be pure hydrogen or a hydrocarbon gas or mixtures thereof, and preferably also a substantial pressure of rare gas such as argon, krypton or xenon.

In this case the bulb 1 itself serves as a support or carrier for a quantity of free carbon 5 which may be in the form of a layer of lamp black or soot on a portion of the inner bulb wall. The bulb 1 is therefore preferably made of compact spherical form and the filament 2 is centered therein. Thereby, the carbon 5 is located within effective range of atomic hydrogen formed in the vicinity of the filament 2. That is, the distance of the bulb wall from the filament is sufficiently small that a substantial amount of atomic hydrogen (H) formed at the filament will reach the bulb wall and the source of carbon 5, before recombining to form molecular hydrogen (H<sub>2</sub>). At the same time, the temperature of the bulb, and therefore the carbon supply 5, is sufficiently low to avoid dissociation of hydrocarbons thereat. For example, at temperatures above about 900° C hydrocarbon such as methane would be strongly dissociated, and the carbon is therefore maintained below that temperature, and preferably below 800° C, during lamp operation.

As a specific example, lamps of the type shown in Fig. 1 have been made with bulbs 1 of borosilicate glass having a diameter of 18 mm and containing 10 volt, 3 ampere coiled filaments 2 made from tantalum wire of 5 mil (=125 microns) diameter which was carburized by heating the filament to incandescence in a hydrocarbon atmosphere as is well known. The bulbs 1 were filled with hydrogen at a partial pressure of about 1 mm Hg and argon at a partial pressure of 600 mm Hg. The hydrogen-carbon cycle performed effectively as evidenced by constancy of the current flow through the filament at constant voltage. Also, carbon was observed to be removed from the bulb wall during operation. Some of the carbon is also deposited on the portions of the lead wires 3 within the bulb which are at a temperature sufficiently high to cause dissociation of the hydrocarbon gas. It will be evident that these deposits of carbon on the leads cannot function as an adequate source of free carbon for combination with atomic hydrogen because the high temperature causes dissociation of hydrocarbons thereat.

In Fig. 2 there is illustrated a form of lamp in which the proximity of the bulb wall to the filament is of no importance. In this case, the carbon is arranged to be located in the gas stream rising from the filament. As illustrated in the drawing, finely divided carbon is coated on a metallic screen 6 arranged to be above the filament 2a. The screen 6 is in this case

carried by a wire support 7 secured to one of the lead wires 3a which are sealed through a re-entrant stem 8 at the lower end of the tubular glass bulb or envelope 1a. The bulb was in this case filled with methane (CH<sub>4</sub>), hydrogen and argon at a partial pressure of 1 mm Hg, 2 mm Hg and 600 mm Hg respectively.

In the Fig. 2 lamp a coating of pyrolytic graphite built up on the legs 9 of the filament coil 2a. A steady state is quickly arrived at in which the position of the high temperature end of the carbon deposit on the filament legs remains fixed as does the current through the lamp. In this case atomic hydrogen formed at the filament 2a is carried upward in the convection currents and reacts with the carbon on the screen 6 forming a hydrocarbon. The hydrocarbon is dissociated at the filament 2a and the carbon from this dissociation arrives at the tantalum carbide filament at a rate equal to the rate of loss of carbon from the tantalum carbide filament by dissociation of tantalum carbide. The hydrocarbon is also dissociated at the coil legs 9 and coats them with carbon. The rate of loss of carbon from solid carbon is about ten times the rate of loss of carbon from tantalum carbide at the same temperature. The carbon coating therefore exists only on the legs 9 of the coil 2a, and not on the turns or body of the coil, because the rate of vaporization of solid carbon (at the temperature of the body of the coil) is greater than the rate of arrival of carbon by dissociation.

In the lamp shown in Fig. 3, the source of free carbon is a coating of soot 5b on the dome-shaped upper end of the tubular bulb 1b which is of relatively large diameter and contains a source of hydrogen and a quantity of inert gas. The carbon 5b is thus in the path of gas currents rising from the filament 2b and carrying therewith carbon volatilized from the filament and atomic hydrogen formed at the filament. The operation of the lamp is similar to that described in connection with the Fig. 2 lamp. The length of the lead wires 3b on which carbon is deposited during lamp operation may be minimized by coating portions of the leads within the bulb with a layer of glass as shown at 10. The filament 2b may be a coiled coil of tantalum carbide dissipating about 150 watts at 21 volts to operate at a temperature of about 3525° K for about 15 hours.

As indicated above, the source of hydrogen in the bulb may be supplied by an initial amount of pure hydrogen or by a hydrocarbon gas such as methane, or a mixture of both. The amount of hydrogen necessary to maintain the cyclic reaction may be quite small. A high pressure of hydrogen is undesirable because of thermal losses occasioned by its high thermal conductivity, resulting in lowered lamp efficiency. The required pressure of

hydrocarbon gas depends upon filament temperature, a lower pressure being required for lower filament temperature. For a filament temperature of about 3100° K it is preferable to employ hydrogen at a partial pressure of about 1 mm Hg; for a filament temperature of about 3400 to 3500° K hydrogen at a partial pressure of about 5 mm Hg is preferred. In general, partial pressure of hydrogen and/or hydrocarbon gas may be employed in the range of about .01 to 20 mm Hg of hydrogen or equivalent hydrogen as hydrocarbon gas. Sufficient rare gas is added to bring the total pressure to about atmospheric or higher when this is compatible with lamp construction and use.

As regards the carbon deposit on the lead wires, in going up the lead wires from the bulb wall toward the filament the temperature increases. When the temperature is such that the rate of dissociation of methane, or other hydrocarbon present, is greater than the rate of formation, a carbon deposit will occur. The other end of the carbon deposit will be the place at which the rate of dissociation of methane, or other hydrocarbon, is just equal to the rate of vaporization of the solid carbon. The carbon deposit will thus occur somewhere on the leads. By keeping the temperature gradient along the length of the filament high, it is possible to minimize the size of the region of this carbon deposit.

When desired, a source of nitrogen may also be added to the lamp atmosphere as, for example, nitrogen itself, or a gas such as hydrogen cyanide (HCN), ammonia, etc. For example, the lamp bulb may be filled with hydrogen cyanide, nitrogen, hydrogen and rare gas such as argon, krypton, or xenon or mixtures thereof. The hydrogen cyanide dissociates into atomic hydrogen and CN. The CN further dissociates in the immediate vicinity of the filament and supplies carbon at a rate to match the rate of loss of carbon from the hottest part of the carbide filament. Atomic hydrogen produced at the filament reacts with the supply of carbon (at 5, 6 or 5b in Figs. 1, 2 and 3) to form methane or some other simple hydrocarbon. This hydrocarbon ends up as HCN again after possibly several intermediate steps. Some of the hydrocarbon will be lost to the lead wires. When this happens, the hydrogen concentration will increase and the rate of attack on the carbon source will increase. In this way the concentration of HCN will remain constant so long as the source of carbon is not exhausted.

The bulb filling may consist of methane (CH<sub>4</sub>), nitrogen and argon. The nitrogen and methane, or other hydrocarbon gas, may be present at a partial pressure of a few mm Hg of each, for example between .01 and 20

mm Hg, with sufficient argon or other inert gas to provide about one atmosphere total pressure. Where nitrogen is added, it is preferably of the same order in amount as the hydrogen and not in excess of the amount of hydrogen.

The function of the rare gas is principally to slow down the various processes, particularly the loss of carbide itself from the filament.

#### WHAT WE CLAIM IS:—

1. An electric incandescent lamp comprising a sealed light-transmissive envelope, and within this envelope, an incandescible filament composed of carbide of a metal of the group consisting of tantalum, hafnium, niobium and zirconium or mixtures thereof, a source of hydrogen, and a quantity of uncombined solid carbon, which carbon is located in effective range of atomic hydrogen formed in the vicinity of said filament and migrating to said solid carbon to effect a cyclic reaction by formation of a carbon-bearing gas available for thermal decomposition in the vicinity of said filament to release carbon for reaction with said filament so as to keep its carbon content at a desired fixed value and to also release hydrogen for continuation of the cyclic reaction.

2. A lamp as set forth in Claim 1 wherein the source of hydrogen is free hydrogen, or a hydrocarbon gas or a mixture thereof at a partial pressure in the range of about 0.01 to 20 mm Hg.

3. A lamp as set forth in Claim 1 or 2 wherein the envelope also contains a substantial pressure of rare gas.

4. A lamp as set forth in any of the Claims 1—3 wherein the envelope also contains a source of nitrogen.

5. A lamp as set forth in Claim 4 wherein the source of nitrogen comprises hydrogen cyanide or nitrogen.

6. A lamp as set forth in any of the Claims 1—5 wherein the uncombined solid carbon is located so as to be maintained, during lamp operation, at a temperature not exceeding about 900° C but is sufficiently close to the filament that sufficient atomic hydrogen, formed at the filament, reaches the said carbon before recombining to form molecular hydrogen, that a cycle is obtained whereby the carbon content of the tantalum carbide filament remains at a desired fixed value.

7. An electric incandescent lamp substantially as described with reference to and as illustrated in any one of the Figures shown in the accompanying drawing.

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FIG. 1.

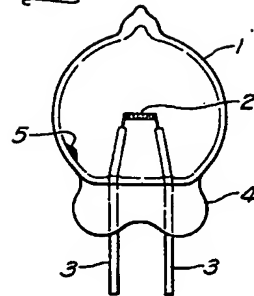


FIG. 2.

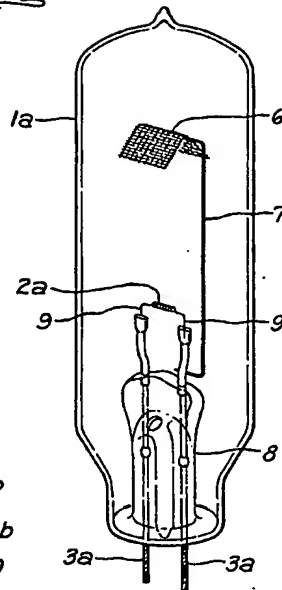


FIG. 3.

